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PHYSICS.—*The relation between birefringence and stress in various types of glass.* L. H. ADAMS and E. D. WILLIAMSON, Geophysical Laboratory, Carnegie Institution of Washington.

When a rigid body is subjected to stress there are produced changes in refractive index which are related to the direction of stress and to the vibration directions of the entering light. Isotropic substances such as glass then become birefracting. It is evident that birefringence may serve as a measure of strain and, consequently, of stress; indeed this method is commonly used for the determination of internal stress in glass, and is of especial importance in the examination of optical glass, which for use in lenses and prisms must be well annealed.

While it is common practice to speak of strain in glass in terms of birefringence, little is known concerning the absolute magnitude of the stresses or strains involved,[1] and, as a part of the general problem of glass annealing, definite information concerning the relation of birefringence to stress was required. Accordingly in this paper we present the results of some measurements of the birefringence due to loading of nine kinds of optical glass. A brief review of the optical effect of stress is also given.

EXPERIMENTAL METHOD AND RESULTS

Blocks of each kind of glass measuring about 2 by 3 by 3 cm. were prepared. The faces were made as nearly plane parallel

[1] The only observations known to us are those by Pockels with reference to several glasses, some of which were flint glasses, while the others were unusual aluminoborates. See page 615 and 620.

as possible, two opposite faces being polished and the other four faces left with a finely ground surface. Each block was in turn subjected to compression in a Riehlé vertical testing machine, and a beam of light polarized by a nicol prism was passed through the block, the plane of polarization of the light being at 45° to the direction of pressure. The blocks of glass when loaded showed a certain amount of double refraction which

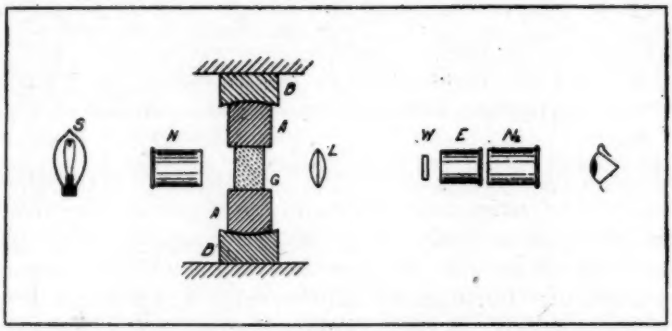

Fig. 1.

Diagrammatic representation of apparatus for measuring birefringence of glass under load. Pressure is transmitted to the block of glass G through the hardened steel blocks A A and B B. Light from the lamp S is polarized by the nicol prism N, passes through the glass, the lens L, the graduated quartz wedge W, the eyepiece E and the analyzing nicol N_2. The nicols are crossed and the axis of thrust makes an angle of 45° with the vibration direction of the light entering the block G.

could be detected by the use of polarized light, and could be measured by determining the optical path difference[2] according

[2] If two rays of light travel with velocities v_a and v_b through the distance l, we have $\frac{v_b}{v_a} = \frac{n_a}{n_b} = \frac{N_a}{N_b} = \frac{\lambda_b}{\lambda_a}$, n_a and n_b being the corresponding refractive indices, λ_a and λ_b the wave-lengths, and N_a and N_b the total numbers of waves. Moreover, $N_a = \frac{l}{\lambda_a} = \frac{n_a l}{\lambda_1}$ in which λ_1 is the wave-length corresponding to $n = 1$. Similarly $N_b = \frac{n_b l}{\lambda_1}$ and

$$N_a - N_b = \frac{(n_a - n_b)l}{\lambda_1}.$$

The product $n_a l$ or $n_b l$, respectively, is called the "optical path;" $(n_a - n_b)l$ is the "optical path-difference" and is the quantity which we measure. Obviously the birefringence $n_a - n_b$ may be obtained by dividing the optical path-difference by the geometrical length of path.

to standard methods.[3] The optical system for measuring the birefringence consisted of a petrographic microscope supported at the proper angle on one post of the testing machine and in such a position that the block of glass G was between the nicol N (Fig. 1) and the low-power lens L. A graduated quartz wedge, W, was in the focal plane of an eyepiece, E, on which was mounted a cap nicol, N_2.

Upon illuminating the system with light from an ordinary incandescent lamp, S, the wedge W—which was placed with its

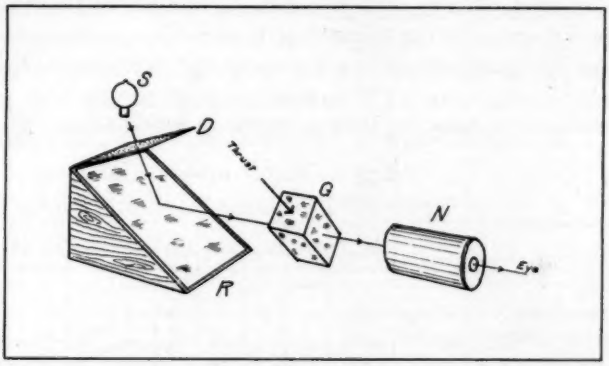

Fig. 2.

Diagram to show arrangement for determining the uniformity of loading. The block of glass G is illuminated by light from S which passes through the diffusing screen D and is reflected from the sheet of glass R. The thrust is applied to the glass in a direction at 45° to the plane of polarization of the light, and the interference colors produced by loading are observed through the analyzing nicol N.

longest dimension in a horizontal position—was observed through the eyepiece and nicol. When the analyzer was placed so that the nicols were crossed, a series of colored lines extended across the field in a vertical direction, and the position of the central black line with respect to the graduations on the wedge determined the birefringence of the specimen. One division on our wedge represented 10 $\mu\mu$ retardation and no difficulty was experienced in reading to $^1/_2$ division or 5 $\mu\mu$, which was about 1 percent of the maximum observed birefringence. The load

[3] For example, see F. E. WRIGHT, *The methods of petrographic-microscopic research*. Carnegie Inst. Wash., Publ. 158, Chap. III. 1911.

could be read to 0.1 kg. or better—a higher degree of precision than is necessary, since readings to within 5 kg. would correspond in accuracy to the readings of the wedge.

The first results obtained were irregular and generally unsatisfactory. This was found to be due to the fact that the load was not applied uniformly. In seeking to remedy this defect we found that the problem of loading a block of glass evenly up to a pressure of a few hundred kg. per sq. cm. offers unexpected experimental difficulties and requires the greatest possible amount of care and patience. Fortunately birefringence serves not only for the quantitative measurement of stress but also for the qualitative examination of the uniformity of stress.

TABLE 1

CHEMICAL COMPOSITION AND OPTICAL PROPERTIES OF THE VARIOUS GLASSES

Kind of glass	Refrac. index n_D	Recipr. rel. dispersion (constringence) ν	Approximate composition								
			PbO	CaO	BaO	ZnO	Na_2O	K_2O	Al_2O_3	B_2O_3	SiO_2
Ordinary Crown.....	1.523	59	—	12	—	—	14	1	—	—	73
Borosilicate Crown...	1.516	62	—	—	4	—	9	8	—	12	67
Light Barium Crown.	1.574	57	—	—	29	11	3	5	1	4	47
Heavy Barium Crown	1.608	57	—	—	43	8	—	—	3	6	40
Barium Flint.....	1.606	44	24	—	15	8	3	4	—	—	46
Light Flint.....	1.573	42	35	—	—	—	6	5	—	—	54
Medium Flint.....	1.616	37	48	—	—	—	3	4	—	—	45
Heavy Flint.....	1.655	33	52	—	—	—	3	3	—	—	42
Extra Heavy Flint...	1.756	27	69	—	—	—	—	3	—	—	28

To detect unevenness of loading a polarizer of large aperture is required. A convenient arrangement is shown in Fig. 2. Light from the lamp S is diffused by the translucent screen D (of ground glass or tracing cloth) and polarized by reflection from the sheet of plate glass R which is painted black on the back. The vibration direction of the beam of light, as with the previous arrangement, is inclined 45° to the direction of pressure. The interference colors are observed through the nicol prism N, no lens being required. If the block of glass G be uniformly loaded it appears in the field of view to be of a certain uniform color

on the Newton scale, the color depending on the amount of birefringence present, but if the load be uneven the color will vary from place to place in bands or streaks or irregular blotches.

After numerous unsuccessful attempts to secure uniform stress throughout the blocks of glass, the following method was found to be satisfactory. The thrust was applied through two hardened steel blocks (A, A in Fig. 1) the curved surfaces of which were in contact with the curved surfaces of the blocks B, B. The adjacent surfaces of steel and glass were ground so as to be as nearly plane as possible and were then ground together with very fine emery. Above and below the block of glass was placed a piece of thin drawing paper. With this arrangement we were able to load the glass uniformly up to a pressure of 200 kg. per sq. cm., which was sufficient for the purpose.

TABLE 2

BIREFRINGENCE PRODUCED IN GLASS BY A THRUST OF 1 KG. PER SQ. CM.

Kind of glass	Path diff. $\mu\mu$ per kg. D/W	Width of block cm. b	$-b \times 10^{-7}$ D/W. Birefringence due to 1 kg. per sq. cm.	Modulus of compressibility. Kg. per sq. cm. K	Modulus of rigidity. R
Ordinary Crown.....	0.959	2.68	-2.57×10^{-7}	0.46×10^{6}	0.28×10^{6}
Borosilicate Crown....	0.852	2.35	-2.85×10^{-7}	0.43×10^{6}	0.29×10^{6}
Light Barium Crown..	0.964	2.92	-2.81×10^{-7}	0.52×10^{6}	0.30×10^{6}
Heavy Barium Crown.	0.638	3.37	-2.15×10^{-7}	0.53×10^{6}	0.29×10^{6}
Barium Flint.....	0.976	3.18	-3.10×10^{-7}	0.42×10^{6}	0.26×10^{6}
Light Flint.....	1.022	3.13	-3.20×10^{-7}	0.35×10^{6}	0.24×10^{6}
Medium Flint.....	1.068	2.93	-3.13×10^{-7}	0.34×10^{6}	0.22×10^{6}
Heavy Flint.....	0.912	2.93	-2.67×10^{-7}	0.34×10^{6}	0.22×10^{6}
Extra Heavy Flint....	0.439	2.78	-1.22×10^{-7}	0.32×10^{6}	0.20×10^{6}

Table 1 shows the chemical composition and optical properties of the glasses used, and in table 2 are given the results of our measurements. If W is the load applied to the block of glass by the testing machine and D the corresponding optical path-difference as determined by the graduated quartz wedge, the ratio D/W was found to be constant for each specimen to within the limit of accuracy of the measurements. This result is in accord with the observation by Brewster[4] in 1814 that the

[4] BREWSTER, Phil. Trans. 1814, 1815, 1816.

optical effect produced is proportional to the amount of the stress.

The ratio D/W, however, is not independent of the dimensions of the block, but it is readily seen that W/ab is the pressure and that D/a is the path difference (b and a are the dimensions of the block measured transversely to the direction of thrust, a being in the direction of the beam of light (see Fig. 1)). Moreover, the ratio

$$\frac{D/a}{W/ab} \text{ or } \frac{bD}{W}$$

is the birefringence produced by unit pressure and is dependent only on the nature of the glass. It is interesting to note that only one dimension of the block needs to be measured. The second column of table 2 gives for each kind of glass the weighted mean value of D/W in $\mu\mu$ per kg., and in the third column are values of b, the width of the block in cm., *i. e.*, the length of an edge perpendicular both to the direction of thrust and the direction of the beam of light. The quantity bD/W as shown in the fourth column is then the birefringence produced by a pressure of 1 kg. per sq. cm. For reasons which will appear later it may be useful to know the rigidity and compressibility of each of the various kinds of glass. In the last two columns of table 2 are given the rigidity and compressibility calculated according to the method described by Hovestadt,[5] except for ordinary crown glass, the compressibility of which we measured by a method already described.[6] These calculated elastic constants are of course only approximate values, but are probably sufficiently accurate for our present purpose.

All of the results in the fourth column lie between 2.57×10^{-7} and 3.20×10^{-7} except for two comparatively uncommon glasses. It is a curious and unexpected circumstance that for the more generally used optical glasses a given stress should produce so nearly the same amount of birefringence. The heavy

[5] H. HOVESTADT, *Jena glass*. Transl. by J. D. and A. EVERETT. London, 1902; pp. 155–160, 185–193.

[6] L. H. ADAMS, E. D. WILLIAMSON and J. JOHNSTON. Journ. Amer. Chem. Soc. 41: 12–42. 1919.

barium crown, containing 43 per cent barium oxide (BaO), and to a still greater extent the extra heavy flint, containing 69 per cent lead oxide (PbO), show a much smaller ratio of birefringence to stress. The variation of this ratio with lead content in the flint glass has been investigated by Pockels,[7] who has expressed his results in a form very different from the one we have used. Before comparing his results with ours it is therefore necessary to give a short discussion of the principles involved.

THE ELEMENTARY THEORY OF OPTICAL EFFECTS PRODUCED BY STRESS

Since the stress at any point in a solid may be resolved into three components at right angles to each other, it is sufficient

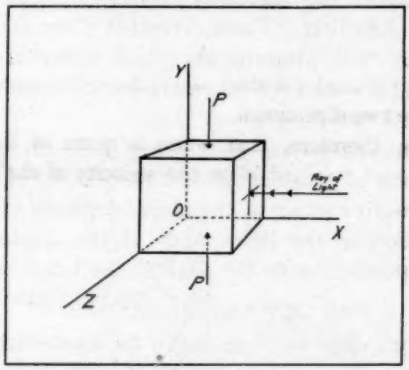

Fig. 3.

Drawing to accompany elementary discussion of optical effects of stress. The thrust P is applied in the direction OY. The ray of light enters the cube of glass in the direction OX, becomes elliptically polarized and is treated as two rays vibrating, respectively, in the directions OY and OZ. Ordinarily the ray vibrating along OY travels with the higher velocity, that is, ordinary glass under uni-directional compression behaves like an optically negative uniaxial crystal.

to consider what happens to light passing through a cube of glass subjected to forces normal to its faces. In Fig. 3 let OX, OY, OZ represent the coordinate axes, and consider a beam of light passing through the cube in a direction parallel to OX. Now if the glass be acted upon by a vertical thrust (*i. e.*, parallel to OY) the cube will be compressed in that direction and ex-

[7] F. POCKELS. Ann. Phys. (4) 7: 745. 1902.

tended along OX and OZ. The velocity of the beam of light will be altered and in general the wave will be split into two wave fronts proceeding with different velocities and polarized in directions at right angles[8] to each other. Moreover, a ray of polarized light after passing through the block of glass in a direction normal to the surface will remain a single ray but will be found to be elliptically polarized and may best be treated as the resultant of two rays vibrating, respectively, along OY and OZ and differing in phase[9] by a certain amount. The compressed block of glass thus behaves as a uniaxial crystal whose optic axis is parallel to OY.

Now a thrust in the direction OZ will produce an effect similar to that in the direction OY, for the cube will be compressed in the direction OZ and extended along OY, but a thrust parallel to OX will produce no phase difference of the rays vibrating along OY and OZ since the cube is extended the same amount in these two directions.

It is evident, therefore, that when a beam of light passes through a block of strained glass the velocity of the light (and hence the refractive index of the glass) depends on (1) the direction of vibration of the light, and (2) the dilatations in those directions perpendicular to the path of the beam of light.

THE GENERALIZED EQUATIONS

The equations used by Neumann[10] for expressing the influence of elastic deformation on the propagation of light are as follows:

$$v_x = v + qx_x + py_y + pz_z \qquad (1_A)$$

$$v_y = v + px_x + qy_y + pz_z \qquad (1_B)$$

$$v_z = v + px_x + py_y + qz_z \qquad (1_C)$$

[8] A ray of light by reflection from a polished surface becomes partially or completely polarized. The plane of polarization is arbitrarily defined as the plane containing the incident and reflected rays, and the direction of vibration is usually taken as the normal to the plane of polarization. The vibration direction so defined is the direction of the electric vibrations of the electromagnetic disturbances and is perpendicular to the magnetic vibrations.

[9] In the actual measurement of birefringence the beam of polarized light is usually arranged to vibrate in a direction at 45° from OY or OZ. The phase difference obviously may be expressed as a path difference by taking account of the wave length of the light.

[10] F. NEUMANN. Ann. Phys. **54**: 1841.

in which x_x, y_y, and z_z are dilatations in the three directions parallel to the three principal axes, v is the velocity of light in the unstressed material, and v_x, v_y, and v_z are the velocities of light waves whose vibrations are parallel to the three axes. p and q are coefficients which are to be determined by experiment.

If n is the refractive index of the unstressed medium and n_x, n_y, and n_z are the refractive indices for light vibrating in the three principal directions, then $nv = n_x v_x = n_y v_y = n_z v_z$ and from Equation (1_A)

$$\frac{v_x - v}{v} = \frac{n - n_x}{n_x} = \frac{q}{v} x_x + \frac{p}{v}(y_y + z_z). \qquad (2)$$

Referring again to Fig. 3, it is obvious that a thrust, P, acting on the block in the direction OY will produce the three principal dilatations:

$$\begin{aligned} x_x &= \sigma P/E \\ y_y &= -P/E \\ z_z &= \sigma P/E \end{aligned}$$

E being Young's modulus and σ Poisson's ratio. Substituting in Equation (2) we have

$$\frac{n_x - n}{n_x} = \frac{P}{E}(1 - \sigma)\frac{p}{v} - \left(\frac{P\sigma}{E}\right)\frac{q}{v} = \frac{P}{E}\left[(1 - \sigma)\frac{p}{v} - \sigma\frac{q}{v}\right]. \qquad (3_A)$$

Similarly it can be shown that

$$\frac{n_y - n}{n_y} = \frac{P}{E}\left(-2\sigma\frac{p}{v} + \frac{q}{v}\right) \qquad (3_B)$$

and

$$\frac{n_z - n}{n_z} = \frac{P}{E}\left[(1 - \sigma)\frac{p}{v} - \sigma\frac{q}{v}\right]. \qquad (3_C)$$

When the coefficients p and q have once been determined, these three equations may be used for calculating the effect of a thrust, P, in the direction OY (Fig. 3) on the three indices of refraction n_x, n_y, and n_z corresponding to light vibrating in the directions OX, OY, and OZ. The changes in refractive index for a given thrust, P, depend on the elasticity constants E and σ, and the coefficients $\frac{p}{v}$ and $\frac{q}{v}$ which are characteristic of the given material and can be determined experimentally.

The change n_x is the same as that of n_z (for a thrust along OY) so that no birefringence is observed for a ray of light passing through the block in the direction OY, but the velocity of a ray in the direction of the triple arrow (*i. e.*, along OX) depends on the direction of vibration, that is, n_x is different from n_z and $n_y - n_z$, by definition, is the birefringence.[11]

Since ordinarily n_x and n_y do not differ from n by more than one part in 1000, we may put with a maximum error of a small fraction of one per cent

$$\frac{n_y - n}{n_y} - \frac{n_z - n}{n_z} = \frac{n_y - n_z}{n}$$

refore by subtracting Equations (3_B) and (3_C) we obtain

$$\frac{n_y - n_z}{n} = \frac{P}{E}(1 + \sigma)\left(\frac{q}{v} - \frac{p}{v}\right). \qquad (4)$$

This equation may be put in slightly different form by making use of the identity

$$R = \frac{E}{2(1 + \sigma)}$$

R being the modulus of rigidity. Substituting this value of R in Equation (4), we have

$$\frac{n_y - n_z}{n} = \frac{P}{2R}\left(\frac{q}{v} - \frac{p}{v}\right). \qquad (5)$$

From Equations (4) and (5) it is evident that the birefringence is proportional to the difference of the two coefficients p and q. Conversely, p and q can not be determined by measurements of birefringence alone, but if in addition to the birefringence we measure the absolute retardation of a ray of light vibrating, say, in the direction OY, both p and q will be uniquely determined.

Suppose now that instead of a thrust we apply to the block of glass a hydrostatic pressure, P'. In order to obtain a relation connecting the coefficients p and q with the *hydrostatic* pressure P', it is obvious from considerations of symmetry that

[11] In the case of a uniaxial crystal, birefringence is usually expressed as $n_\epsilon - n_\omega$, which is identical with $n_y - n_z$, the direction Y being the direction of the optic axis.

it is sufficient to add the three Equations, (3_A), (3_B), and (3_C). Then, since $\frac{n - n_x}{n_x}$ is approximately equal to $\frac{n - n_x}{n}$, we have

$$\frac{n_x - n}{n} = \frac{P'}{E}(2 - 4\sigma)\frac{p}{v} + \frac{P'}{E}(1 - 2\sigma)\frac{q}{v} = \frac{P'}{E}(1 - 2\sigma)\left(\frac{2p}{v} + \frac{q}{v}\right) \qquad (6)$$

By putting $\frac{E}{3(1 - 2\sigma)} = K$, in which K is the modulus of volume-elasticity,[12] the equation becomes

$$\frac{n_x - n}{n} = \frac{P'}{3K}\left(\frac{2p}{v} + \frac{q}{v}\right) \qquad (7)$$

which expresses in terms of known or measurable quantities the effect of hydrostatic pressure on the index of refraction, which of course under these conditions remains independent of the plane of polarization of the light.

COMPARISON WITH POCKEL'S RESULTS

The optical effects of stress on several kinds of glass have been studied by Pockels,[13] who loaded rectangular plates of the glasses and measured with a Jamin interferometer the absolute retardation of a ray of light vibrating parallel to the direction of pressure. He also measured the birefringence with a Babinet compensator and from the two series of measurements calculated the values of $\frac{p}{v}$ and $\frac{q}{v}$. His results are shown in table 3. The first column describes the glass, the second gives its number in Winkelmann's list;[14] in the third and fourth columns are the elastic constants of the glass; the index of refraction n is shown in the sixth column, and the percentage of lead oxide in the seventh. In the next two columns are the results of Pockels' determination of $\frac{p}{v}$ and $\frac{q}{v}$, the coefficients which occur

[12] $1/K = \beta$, the compressibility at constant temperature.

[13] F. POCKELS. Ann. Phys. (4) 7: 745. 1902.

[14] Compare HOVESTADT, *op. cit.*, p. 146.

in Equations (1) to (7) of this paper. Substituting these values in Equation (4) we have calculated the birefringence $n_y - n_z$ caused by a thrust of 1 kg. per sq. cm. and have placed the values obtained by this calculation in the last column of table 3.

We are now able to make a comparison between our results and those of Pockels. The first three glasses in table 3 are unusual alumino-borates, but the remaining four form a series of flint glasses with lead content varying over a wide range. In Fig. 4, for the sake of comparison, our results for the flint

TABLE 3

RESULTS OF POCKELS' MEASUREMENTS ON OPTICAL EFFECTS OF STRESS

Kind of glass	Winkelmann's No.	E Young's modulus 10^6 kg. per sq. cm.	σ Poisson's ratio	n Refrac. index	Percentage of PbO in glass	Coefficients of Equation (1)		Birefringence due to 1 kg. per sq. cm. calc. from Equation (4)
						$\frac{p}{p}$	$\frac{q}{p}$	
Sodium Alumino-borate.....	2	0.480	0.274	1.508	—	0.274	0.166	—4.32
Lead Alumino-borate.....	42	0.472	0.268	1.512	32.	0.0908	0.0228	—2.76
Lead Alumino-borate.....	21	0.547	0.250	1.545	25.	0.289	0.182	—3.78
Light Flint.....	47	0.610	0.222	1.570	33.	0.306	0.213	—2.93
Heavy Flint.....	26	0.547	0.224	1.644	51.7	0.335	0.264	—2.61
Extra Heavy Flint	33	0.550	0.239	1.751	67.5	0.354	0.319	—1.38
Heaviest Flint...	20	0.503	0.261	1.963	80.	0.427	0.466	1.92

glass and also those of Pockels have been plotted with PbO content as abscissa and birefringence due to 1 kg. per sq. cm. as ordinate.

By inspection of Fig. 4 it may be seen that Pockels' results for the flint glasses on the whole agree very well with ours. It should be noted, however, that the content of PbO does not completely determine the character of the glass and that therefore certain small discrepancies between Pockels' results and ours as indicated by Fig. 4 may not have a real existence.

It is interesting to note that ordinarily q is less than p. When this is the case the birefringence $n_y - n_z$ by Equation (5) is negative. But for the heaviest flint (PbO = 80 per cent) in-

vestigated by Pockels (see table 3) q is greater than p and therefore this glass when acted upon by a thrust shows positive double refraction.[15] Since the next flint glass in the series (PbO = 67.5 per cent) exhibits negative birefringence, it is evident that there must be some intermediate flint glass for which the birefringence would be zero and which therefore would remain isotropic under the influence of any elastic deformation. In attempting to make such a glass the composition 74.6 per cent PbO, 23.6 per cent SiO_2, 0.6 per cent (K_2O + Na_2O) was

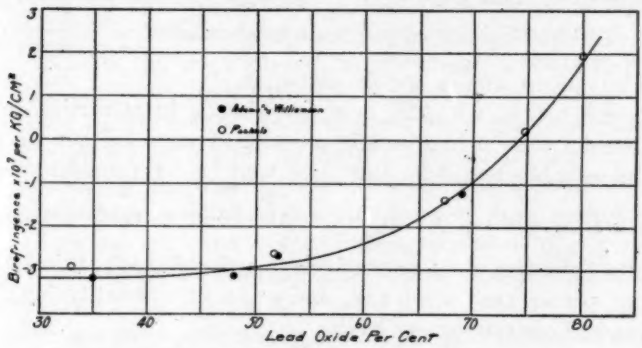

Fig. 4.

Graphical representation of the results for the *flint* glasses. The abscissa is % PbO and the ordinate is the birefringence caused by a *thrust* of 1 kg./cm².

tried by Pockels, and was found to give positive birefringence of 0.2×10^{-7}. This datum has also been plotted in Fig. 4, from which it can be seen that a glass containing about 74.0 per cent PbO would, no matter how poorly annealed, show no birefringence.

APPLICATION TO PROBLEMS DEALING WITH GLASS

As an example of the way in which the results given in this paper may be used, suppose that a sheet of ordinary crown glass be observed between crossed nicols and illuminated with white light, and suppose that in looking through 10 cm. of the sheet the interference color in a certain part of the cross-section is seen to be a red of the first order. In order to ascertain the

[15] It should be remembered that in Equations (3), (4) and (5), P is a thrust. If P be a tension most glasses will show positive double refraction.

internal stress corresponding to the observed color we find, by referring to a chart[16] showing Newton's color scale in terms of optical path-difference, that a first-order red corresponds to a retardation of about 530 $\mu\mu$ or 530×10^{-7} cm. The birefringence then is the path-difference per unit of length, that is, $\frac{530 \times 10^{-7}}{10} = 53 \times 10^{-7}$. Now, according to table 2, a birefringence of 2.57×10^{-7} corresponds in ordinary crown glass to a (uni-directional) pressure of 1 kg. per sq. cm. Hence the observed birefringence corresponds to a stress of $\frac{53 \times 10^{-7}}{2.57 \times 10^{-7}} =$ 20.6 kg. per sq. cm. or 300 lb. per sq. in.[17]

In conclusion, we shall note the change in refractive index produced (1) by a hydrostatic pressure of 1000 kg. per sq. cm. acting on a block of light flint glass; and (2) by a uni-directional pressure of 1000 kg. per sq. cm. According to table 3, $\frac{p}{v}$ and $\frac{q}{v}$ are, for light flint glass, respectively, 0.306 and 0.213; E is 0.61×10^6 kg. per sq. cm.; σ is 0.222; and n is 1.57. Substituting these values in Equation (6) we have

$$n_x - n = \Delta n = \frac{10^3(1-0.444)(0.612+0.213)1.57}{0.61 \times 10^6} = 0.00118.$$

The index of refraction is thus increased 0.0012 by a pressure (hydrostatic) of 1000 kg. per sq. cm., and this change in index is independent of the plane of polarization of the light. On the other hand, for the case of a uni-directional pressure, we use Equations (3_a) and (3_c), and suppose that, as in Fig. 3, the pressure is exerted along OY, and that the ray of light travels along OX. Then

$$n_y - n = \Delta n_\alpha = \frac{1.57 \times 1000}{0.61 \times 10^6}(0.213 - 0.444 \times 0.306) = 0.00020$$

[16] See, for example, the chart in J. P. IDDINGS, *Rock Minerals* (1911); or N. H. WINCHELL, *Optical Mineralogy* (1909).

[17] We have observed, in poorly annealed glass, stresses very much higher than 300 lb. per sq. in. By taking into account the sign of path-difference in polarized light, it is easy to show that the stress in the center of a slab of unannealed glass consists of a tension in all directions parallel to the large surface of the slab.

and

$$n_z - n = \Delta n_\gamma = \frac{1.57 \times 1000}{0.61 \times 10^6}(0.306 \times 0.778 - 0.213 \times 0.222) = 0.00049.$$

That is, a thrust of 1000 kg. per sq. cm. changes the refractive index 0.00049 for a ray vibrating perpendicular to the axis of pressure and only 0.00020 for a ray vibrating in the direction of the thrust.

SUMMARY

Glass when stressed becomes doubly refracting as shown by its behavior in polarized light. This principle has often been made use of in the detection and measurement of strain in glass, but little has been known of the quantitative relation between stress and birefringence. In this paper we have presented the results obtained by loading blocks of glass in a testing machine and measuring the concomitant birefringence. For all of the glasses which we studied except the heaviest flint, a thrust of one kg. per sq. cm. produces a birefringence of 2 to 3 $\times 10^{-7}$; or, in other words, a path-difference of 2 to 3 $\mu\mu$ per cm. thickness of glass.

Our results show satisfactory agreement with those of Pockels for the flint glasses.

ZOÖGEOGRAPHY.—*Discontinuous distribution among the echinoderms.* AUSTIN H. CLARK, U. S. National Museum.

While discontinuous distribution among terrestrial and fresh-water animals has received a considerable amount of attention, the same phenomenon among marine types has not been so widely noticed.

The following apparently anomalous ranges are occupied by the genera of brittle-stars, starfishes and urchins listed; there are no similar cases among the crinoids; and the holothurians, on account of the relatively unsatisfactory state of our present knowledge, have been omitted.

1. Warmer parts of the eastern and western Atlantic; Mexico to Chile: *Narcissia, Arbacia.*

2. Both coasts of tropical America: *Encope, Mellita.*

3. Caribbean Sea and the western coast of Central America: *Hemipholis, Ophiocryptus, Ophiozona.*

4. Caribbean Sea and the Galápagos Islands (probably in reality the same as the preceding): *Sigsbeia.*

5. Peru to southern California (some only in part): *Astrocaneum, Diopederma, Gymnophiura, Platasterias, Nidorellia, Amphiaster, Paulia* (Galápagos Islands also), *Pharia, Phataria, Gaenocentrotus* (Galápagos Islands also), *Tetrapygus.*

6. Caribbean Sea and eastern Atlantic, the Hawaiian Islands, southern Japan and the Kei Islands: *Caenopedina.*

7. Western coast of Mexico, the Hawaiian Islands, Australia, Tasmania, Lord Howe Island, the Mediterranean Sea and the adjacent parts of the Atlantic: *Centrostephanus.*

8. Southern and Lower California, southern Japan and southern Australia: *Heliocidaris.*

9. Caribbean Sea and the Hawaiian Islands: *Podocidaris.*

10. Caribbean Sea and southern Australia: *Ophioprium.*

11. Southern California and New Zealand: *Ophiopteris.*

In view of the past intercommunication between the Caribbean Sea and the Pacific the similarity of certain elements of the Caribbean fauna and of that of the western coast of tropical America is not surprising; the latter, however, includes a very considerable number of genera which occur nowhere else, together with a few species of characteristic Indo-Malayan types, such as *Mithrodia, Acanthaster, Anthenea, Leiaster, Astropyga,* etc., which are not represented in the Caribbean Sea.

A significantly large number of genera, including well-known and conspicuous littoral types, inhabit a more or less extensive portion of the following anomalous range: Mediterranean Sea, Caribbean Sea, southern Australia and New Zealand, southern Japan, the Hawaiian Islands, and the western coast of tropical America.

This discontinuous range, though indicated by very diverse types and only in part by each, nevertheless must be considered a zoögeographic unit. Its outstanding feature is the fact that it represents the extreme outer limits of a tropical and subtropical faunal region the center of which is the Indo-Malayan region.

The types inhabiting it, that is to say, occurring only on the extreme periphery of the Indo-Pacific faunal area (of which the Mediterranean Sea was at one time a part), may be considered, therefore, as relics of a previous fauna at one time characteristic of the central Indo-Malayan region, from which they have now been extirpated through the competition of younger and more efficient types.

The same facts are brought out equally well in many other groups of marine animals, and are also reflected in a modified way in the terrestrial faunas.

In the faunas of the colder seas all intergradations are found between types which are quite unique and types differing little or not at all from others in the Indo-Malayan region, and this intergradation is complete enough so that we are justified in considering the fauna of the colder waters as similarly ultimately derived from the (past or present) fauna of the East Indian region largely through the intermediary of deep water forms. Some of these genera of the colder waters, as *Astriclypeus* and *Glyptocidaris*, are extraordinarily restricted in their distribution and rare, while others are abundant and widely spread.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEODESY.—*General instructions for precise and secondary traverse.* U. S. Coast and Geodetic Survey, Special Publ. **58** (serial 111). Pp. 48, figs. 5. 1919.

The instructions are designed for the highest class of traverse, equal in accuracy to primary triangulation, and for secondary traverse comparable in accuracy with secondary triangulation. R. L. F.

APPARATUS.—*A furnace temperature regulator.* WALTER P. WHITE and LEASON H. ADAMS. Phys. Rev. **14**: 44–48. July, 1919.

By making the heating coil of an electric furnace one arm of a wheatstone bridge, and combining this with a galvanometer regulator, thus keeping constant the resistance of the coil, we can, regardless of variations in the current-supply, and with no attention, maintain constant the temperature of furnaces not too directly influenced by the temperature of the room, or where the surrounding air is kept constant. The power available in this regulator is relatively very great; nothing has to be inserted within the furnace cavity, and the lag is practically nothing; the regulator is often nearly at its best under conditions most unfavorable to other regulators. It has held a small furnace for hours constant to 0.1° at temperatures from 500° to 1400°C.

W. P. W.

PHYSICS.—*Temperature distribution in solids during heating or cooling.* E. D. WILLIAMSON and L. H. ADAMS. Phys. Rev. **14**: 99–114. August, 1919. (Geophysical Lab. Papers on Optical Glass, No. 11.)

In deciding on the best methods of carrying out various operations in the manufacture of optical glass, it was found necessary to have some idea of the temperature gradients in the pieces during heat treatment.

While great precision in absolute magnitudes is generally of minor importance in such cases, the only way to gain insight into the question of the variation of the temperature differences with the shape and dimensions of the blocks and the method of heating is actually to work out numerical cases.

Equations have been derived for the temperature distribution in solids of several typical shapes, the solids being heated or cooled according to one of two methods, *viz.*, the surface of the body (1) is continuously heated (or cooled) at a uniform rate; or (2) experiences a sudden change to a higher or lower constant temperature. With these equations a number of calculations have been made and the results of the computations are presented in tabular form and, in certain cases, are also shown graphically. By the use of these tables and graphs it is a comparatively simple matter to determine the temperatures within solids of a large variety of shapes when, as is commonly the case, they are heated or cooled according to one of the methods mentioned above.

The equations given are in convenient form for calculation and for showing a number of interesting qualitative relations between the temperature gradients in various solids, and they will probably prove useful in connection with the determination of specific heat and thermal conductivity by dynamic methods.

While the main interest at the time was in the application to glass manufacture, the equations are perfectly general, as are also the qualitative deductions made. E. D. W.

PHYSICS.—*Silicate specific heats. Second series.* WALTER P. WHITE. Amer. Journ. Sci. **47**: 1–43. Jan., 1919.

Specific heats of various forms of silica and silicates were determined for upper temperatures from 100° to 1400°. The method was by droping from furnaces into calorimeters. Two new methods are described for determining true or atomic heats from interval heats. On the whole, the general temperature variation of the specific heats is one depending mainly on the value of ν, the atomic vibration period, for oxygen in combination. Several forms of silica, whose expansion is very small, and which therefore practically give values of specific heat at constant volume, C_v, show that C_v for high temperatures appears to exceed the theoretical value 5.96. Glasses show, in the main, a specific heat only slightly above the corresponding crystal forms, but with a tendency to increase at some rather high temperature. In several sets of polymorphic forms with sluggish inversions there were differences of about

2 per cent between the two forms, but none of these forms showed any variation in specific heat near the inversion temperature. In quartz, below the α-β inversion at 575°, the heat absorption is greater than can be accounted for even by the abnormal expansion. If such absorption, unusual change of volume, and change of crystal properties are each or all together the sign of a change of state, then quartz undergoes a gradual change of state over an interval of 400° below what is commonly called its α-β inversion. Quartz and probably other forms of silica exhibit what appear to be two kinds of inversion, due to different mechanisms. Some of these facts militate against certain hypotheses which make polymorphism the resultant of polymeric or isomeric changes in the solid. W. P. W.

INORGANIC CHEMISTRY.—*The hydrated ferric oxides.* EUGEN POSNJAK and H. E. MERWIN. Amer. Journ. Sci. **47**: 311–348. May, 1919.

Microscopic and chemical studies show that no series of hydrates of ferric oxide exists among the natural minerals. The only existing hydrate is ferric oxide monohydrate. This substance occurs in nature in two polymorphic forms—goethite and lepidocrocite—and in an "amorphous" condition—limonite. The two crystallized forms are contrasted as follows:

Goethite.—Orthorhombic, $a : b : c = 0.91 : 1 : 0.602$; density (grams per cc.) 4.28 ±0.01; $\alpha = 2.26$, $\beta = 2.394$, $\gamma = 2.400$; streak, dull orange-yellow; pleochroism faint. When crystallized in dense aggregates of thin blades and fibers inclosing much adsorbed and capillary water, it has commonly been called limonite; however, sufficient proof is now given to show that such crystallized material is really goethite.

Lepidocrocite.—Orthorhombic, $a : b : c = 0.43 : 1 : 0.64$; density, 4.09 ± 0.04; $\alpha = 1.94$, $\beta = 2.20$, $\gamma = 2.51$; streak, dull orange; pleochroism very strong.

The name *limonite* is retained for material which appears to be essentially isotropic ferric oxide monohydrate with adsorbed and capillary water. However, this substance should not be considered a distinct form of ferric oxide monohydrate, as the real nature of such "amorphous" substances is still uncertain.

The fibrous mineral *turgite* is variable in composition, and considerable evidence is given that it probably represents solid solutions of goethite with hematite, together with inclosed and adsorbed water.

The genetic conditions of the hydrated ferric oxides and the stability relation of the two monohydrates are unknown.

No definitely crystallized synthetic hydrated ferric oxide has up to the present been prepared. However, it seems certain that only two distinct types of "amorphous" hydrated ferric oxide exist, one yellow and the other reddish brown. The yellow is apparently essentially ferric-oxide monohydrate, while the reddish brown substance may hold its water in either a dissolved or an adsorbed condition (or both). Thus the synthetic and the natural hydrated ferric oxides exhibit, chemically, great similarity. H. E. M.

INORGANIC CHEMISTRY.—*The ternary system CaO–MgO–SiO₂.* J. B. FERGUSON and H. E. MERWIN. Proc. Nat. Acad. Sci. **5**: 16–18. 1919. (Preliminary.) Amer. Journ. Sci. **48**: 81–123. Aug., 1919.

The crystalline phases which are definite compounds and which appear as primary phases are as follows: Lime; magnesia; silica (tridymite and cristobalite); α-$CaO.SiO_2$ (pseudowollastonite); $3CaO.2SiO_2$; α- and β-$2CaO.SiO_2$; $MgO.SiO_2$ (clino-enstatite); $2MgO.SiO_2$ (forsterite); $CaO.MgO.2SiO_2$ (diopside); $5CaO.2MgO.6SiO_2$; and $2CaO.MgO.2SiO_2$. The melting point of $2CaO.MgO.2SiO_2$ is 1458° ± 5°C. and the decomposition temperature of $5CaO.2MgO.6SiO_2$ is 1365° ± 5°C. In addition to these, crystals representing several solid solutions also appear as primary phases. The solid solutions are: 1. A complete series with clino-enstatite and diopside as end members, generally known as pyroxenes. 2. The pseudowollastonite solid solutions. 3. The wollastonite solid solutions. 4. The $5CaO.2MgO.6SiO_2$ solid solutions. 5. Certain members of the monticellite ($CaO.MgO.SiO_2$) solid solutions. Monticellite itself probably decomposes at too low a temperature to ever occur as a primary phase.

The temperature-concentration relations of the liquids which may be in equilibrium with each of these phases have been thoroughly investigated where necessary, by means of the quenching method, and the results obtained have been correlated with the existing data on the remainder of the ternary system. The compounds $5CaO.2MgO.6SiO_2$ and $2CaO.MgO.2SiO_2$ (akermanite) have not been prepared previously. Attempts to prepare a compound of the formula $8CaO.4MgO.9SiO_2$ (Schaller's akermanite) gave negative results. The monticellite solid solutions and the compound akermanite are discussed at length but the wollastonite and the $5CaO.2MgO.6SiO_2$ solid solutions are only briefly mentioned as they are made the subject of a subsequent paper.

Experiments were made on the tridymite-cristobalite inversion temperature, which was found for this system to be below 1500°C., in approximate agreement with Fenner's original value of 1470°.

J. B. F.

INORGANIC CHEMISTRY.—*Wollastonite ($CaO.SiO_2$) and related solid solutions in the ternary system lime–magnesia–silica.* J. B. FERGUSON and H. E. MERWIN. Amer. Journ. Sci. **48**: 165–189. September, 1919.

The study of the ternary system $CaO–MgO–SiO_2$ brought to light many perplexing liquidus relations for which there was no adequate explanation. An investigation of the solidus relations was therefore started in order to clear up the doubtful points, and the results of this investigation are given in this paper. The salient features of these results are: (1) A confirmation of the earlier work in regard to the wollastonite-diopside solid solutions, wollastonite taking up a maximum of 17 per cent of diopside. (2) The existence of solid solutions of pseudowollastonite and diopside containing as a maximum about 16 per cent of diopside. (3) The finding of the new compound, $5CaO.2MgO.6SiO_2$. (4) The existence of solid solutions of akermanite (or perhaps of an unstable compound, $3CaO.MgO.3SiO_2$) in wollastonite and pseudowollastonite. The wollastonite solutions extend to a composition containing between 60 and 70 per cent of akermanite, while the pseudowollastonite solutions extend to a composition containing about 23 per cent of the same compound. (5) The presence of an area of solid solution which includes the wollastonite-diopside, the wollastonite-akermanite, and the wollastonite-$5CaO.2MgO.6SiO_2$ solid solutions.

In addition to the results just mentioned, which suffice to clear up the liquidus relations in question, as thorough an investigation as the nature of the problem and the available methods of attack would permit was carried out upon the solid solutions of silica and $3CaO.2SiO_2$ in calcium metasilicate and upon the inversion and decomposition temperatures of all the various solid solutions. A general discussion of these results with diagram and models, is given.

J. B. F.

ANALYTICAL CHEMISTRY.—*Electrometric titrations, with special reference to the determination of ferrous and ferric iron.* J. C. HOSTETTER and H. S. ROBERTS. Journ. Amer. Chem. Soc. **41**: 1337–1357. September, 1919.

The advantages of the electrometric method for titrating, oxidizing, and reducing reactions may be summarized as follows: (1) This

method permits the use of potassium dichromate with its numerous advantages. (2) The reduction of the solution with electrometric control eliminates the removal of excess reducing agent, which must be done with the usual methods of reduction. (3) Conditions, such as acidity, need not be controlled, except within very wide limits, and hydrochloric, sulfuric, or hydrofluoric acid, or mixtures of these, may all be used. In contrast to these wide limits, compare the narrow acid limits (1.5 to 2.5 per cent by volume of H_2SO_4) within which the reduction with SO_2 or H_2S must be carried out and the precautions which must be taken in a permanganate titration in the presence of either chlorides or fluorides. (4) The sensitivity and accuracy of the method make possible (*a*) the determination of a few tenths of a milligram of tin, chromium, ferrous or ferric iron, and probably many other elements, in the presence of large quantities of some other element, and (*b*) the determination of blanks involved in some of the ordinary determinations by reducing or oxidizing agents. (5) The time within which a determination can be carried out is greatly shortened. The content of ferrous and ferric iron in a silicate, for instance, can be determined in from 15 to 30 minutes. (6) The precision attainable is comparable to the best of the ordinary volumetric determinations. J. C. H.

ANALYTICAL CHEMISTRY.—*Electrical apparatus for use in electrometric titration.* HOWARD S. ROBERTS. Journ. Amer. Chem. Soc. **41**: 1358–1362. September, 1919.

A description of simplified and inexpensive apparatus for use in the titration of salts by the electrometric method. The potentiometer consists of a sliding rheostat with attached scale. Several forms of galvanometer may be used. H. S. R.

GEOLOGY.—*Upper Cretaceous floras of the eastern gulf region in Tennessee, Mississippi, Alabama and Georgia.* EDWARD WILBER BERRY. U. S. Geol. Survey, Prof. Paper **112**: 7–172. pls. 33, figs. 12. 1919.

Besides describing the floras, the author discusses in detail the distribution, lithologic character, stratigraphic relations, and local sections of the Tuscaloosa, Eutaw, and Ripley formations, and Selma chalk. As the bulk of the flora is from the Tuscaloosa formation and the representation of the Eutaw and Ripley floras is too meager to throw any considerable light upon their correlation or the physical conditions accompanying deposition, this contribution is devoted prin-

cipally to the elucidation of the Tuscaloosa flora, which, as described in the systematic chapter, embraces 151 species. The present treatment is conservative, as a considerable number of additional forms represented in the collections by incomplete material have been left uncharacterized. R. W. STONE.

GEOLOGY.—*Water-power investigations and mining developments in southeastern Alaska.* G. H. CANFIELD, THEODORE CHAPIN, and R. M. OVERBECK. U. S. Geol. Survey Bull. **692-B.** Pp. 94 (43–136), pls. 2. 1919.

Contents:

1. *Water-power investigations in southeastern Alaska.* GEORGE H. CANFIELD.

2. *Mining developments in the Ketchikan district.* THEODORE CHAPIN.

3. *Geology and mineral resources of the west coast of Chichagof Island.* R. M. OVERBECK.

1. Consists of gaging station records.

2. A brief note on mining in Ketchikan district in 1917.

3. The complex geology of the west coast of Chichagof Island is the result largely of extensive intrusion, which has metamorphosed the rocks cut by the intrusive bodies and has complicated their structure. The geology of the island is discussed under the following heads: (1) Undifferentiated metamorphic rocks; (2) graywacke; (3) igneous rocks; (4) development of the topographic features. The rocks of the undifferentiated metamorphic series are sheared conglomerate, limestone, argillite, tuff, flow rock, and intrusive rock, and several types of schist. No determinable fossils were found in these rocks; and although the rocks constituting this series may be of different ages, they are probably older than Jurassic or Lower Cretaceous. The graywacke series consists of graywacke, of some slaty and argillaceous beds, and of a little greenstone. The igneous rocks are both intrusive rocks and flow rocks. Granite, quartz diorite, diorite, alaskite, aplite, hornblende gabbro, norite, greenstone, and possibly some andesite, are the types of rocks represented. Quaternary deposits are practically absent, but the results of the action of the ice are remarkably well shown by the topographic features. Mines and prospects of gold, copper and nickel are described. R. W. STONE.

GEOLOGY.—*Mining and mineral deposits in the Cook Inlet-Susitna region, Alaska.* STEPHEN R. CAPPS, J. B. MERTIE, JR., and G. C. MARTIN. U. S. Geol. Survey, Bull. **692-D.** Pp. 106 (177–282), pls. 3, figs. 4. 1919.

Contents:

1. *Gold lode mining in the Willow Creek district.* STEPHEN R. CAPPS.
2. *Mineral resources of the western Talkeetna Mountains.* STEPHEN R. CAPPS.
3. *Mineral resources of the upper Chulitna region.* STEPHEN R. CAPPS.
4. *Platinum-bearing gold placers of the Kahiltna Valley.* J. B. MERTIE, JR.
5. *Chromite deposits in Alaska.* J. B. MERTIE, JR.
6. *Geologic problems at the Matanuska coal mines.* G. C. MARTIN.

1. Quartz lodes in the Willow Creek district, Alaska, where mining has been done since 1908, have yielded more than $1,600,000 in gold and silver and are still being worked profitably. The character of the deposits and the work done in the district in 1917 are described.

2. The western Talkeetna Mountains have long been considered a promising field for the prospector, but the only productive part of it thus far is the Willow Creek district. The construction of lines of Government railroads to the region has made information concerning the region especially timely and valuable. A sketch map of the region is given and its geography and geology as well as the vegetation, game, and routes of travel, are described.

3. The mineral prospects in the upper Chulitna region lie 15 to 30 miles southwest of Broad Pass and include both gold lodes and gold placers. For several years work has been done on lode claims in this remote region, which will be made more easily accessible by the Government railroads. The bulletin includes a sketch map of the region and a description of its geography, geology, vegetation, and game animals, and details of the claims and prospects.

4. Mr. Mertie gives a geologic sketch map of the Kahiltna Valley, describes its geography and geology, and presents an account of its mineral resources, which includes descriptions of the placers on many creeks. Though gold is the only mineral thus far recovered in commercial quantities the placers have yielded small quantities of other valuable minerals, which include platinum and ores of tin and tungsten.

5. The chromite deposits of present interest in Alaska are at the

southwest end of Kenai Peninsula. A description of the deposit now mined and a map showing its location are given in the bulletin.

6. The results of studies of the strata and of the structure in the Matanuska coal field, Alaska, made in 1917, are reported. The paper includes sections showing the character, relations, and thickness of the beds of rock and coal at many localities, as well as a graphic section showing a tentative correlation of certain coal beds between places specified. G. C. M.

GEOLOGY.—*Sulphur deposits and beach placers of southwestern Alaska.* A. G. MADDREN. U. S. Geol. Survey, Bull. **692-E.** Pp. 37 (283–319), pls. 2, figs. 6. 1919.

Sulphur deposits: Sulphur-bearing deposits at three localities in southwestern Alaska—in the crater of Makushin Volcano on Unalaska Island, on Akun Island, and near Stepovak Bay on the Alaska Peninsula, are of the volcanic type termed solfataras—that is, they are surface deposits formed by sublimation from hot sulphurous volcanic vapors. They are situated in the belt of active and quiescent volcanoes that extends throughout the Alaska Peninsula, the Aleutian Islands, and Japan.

Makushin Volcano, about 6,000 feet in altitude, is in the northern part of Unalaska Island, about 12 miles west of Dutch Harbor. The floor of the crater is 300 to 500 feet below the higher crags of the rim, but the floor of the basin is exposed only in an area of 20 to 30 acres, where the sulphur deposits occur. Except in this bare area the basin is occupied by glacial ice and snow. It is evident that the main solfataric area is kept bare by subterranean heat. As a whole the sulphur-bearing deposit is earthy and appears to be composed chiefly of siliceous residual products of rock decomposition that have resulted from the highly corrosive chemical action of the hot solfataric vapors on the basalt. The richer deposits of sulphur occur within 2 feet of the surface, but there is also more or less finely divided sulphur disseminated to a depth of at least 16 feet. The commercial bodies of sulphur in this deposit are clearly surficial. The percentage of sulphur at the surface does not indicate that rich deposits exist at depth, as is usually believed by the optimistic prospector.

The sulphur at Akun Island deposit occurs chiefly in the form of crystalline incrustations one-sixteenth to one-eighth of an inch thick on the walls of narrow crevices and small cavities in the porous earthy surface zone.

The sulphur-bearing rock near Stepovak Bay consists of porous volcanic breccia that contains compact crystalline sulphur in veins one-eighth to one-fourth inch thick.

Beach placers: The rocks of Kodiak Island and the neighboring islands consist chiefly of slates and graywackes, which are cut by numerous but for the most part small intrusive masses, partly granitic. Schists that probably underlie the slates and graywackes are present along the northwestern part of the island, and small areas of poorly consolidated Tertiary sediments are reported to lie along the southeastern flanks of the island. Quaternary sediments that consist of ground moraine overlain by glacial outwash gravels and recessional moraines occupy the floors of all the larger valleys and form a considerable belt of coastal plain along the west coast.

All the gold-placer deposits so far discovered on Kodiak Island are confined to the present ocean beaches and practically no valuable placer concentrations have been found in any of the present stream gravels. The evidence presented by the topographic development of Kodiak Island shows that postglacial wave erosion and concentration along the shores of the island, especially along the shores composed of unconsolidated fluvioglacial sediments, is the most active agency favorable to the formation of placer deposits.

Earthquakes of considerable violence are known to occur frequently in this part of Alaska, and they may accelerate erosion, especially in tracts of unconsolidated sediments such as the coastal plain here considered, where steep escarpments facilitate the delivery of loosened material upon a beach where it may be directly attacked by heavy surf. However, storms of unusual intensity or duration are the chief factors in concentrating the loose beach deposits and forming the temporary segregations of placer sands.

The chief minerals that make up the heavy concentrates of the beach comprise magnetite, pyrite, chromite, gold, and a little platinum.

R. W. STONE.

GEOLOGY.—*Mining in Fairbanks, Ruby, Hot Springs, and Tolstoi Districts, Alaska.* THEODORE CHAPIN and GEORGE L. HARRINGTON. U. S. Geol. Survey, Bull. **692-F.** Pp. 31 (321–351), pl. 1, fig. 1. 1919.

The Fairbanks district, in the Yukon basin, has produced over $70,000,000 in gold and has been a source of considerable silver, lead, tungsten, and antimony Mr. Chapin gives an account of the opera-

tions at the gold and the silver-lead lodes and at the tungsten deposits in 1917.

A molybdenite-bearing quartz vein on Healy River, Alaska, which has been traced by shallow openings for the length of three claims, is the subject of a brief note.

The Hot Springs district, in Alaska, has produced more than $6,000,000 in placer gold, as well as some silver and tin. Mr. Chapin describes the occurrence of tin ore in the district, and gives an account of the mining operations there in 1917. Stream tin has been found in gold placers in the Ruby district at several places, but not in quantities large enough to pay for mining it except as an accessory to the gold.

The Tolstoi district, Lower Yukon basin, includes an area about 12 miles wide by 20 miles long, which lies on the flanks of Mount Hurst in the basin of Tolstoi River, on the branches of which placers that yield gold and platinum have been worked for several years. The topography, geology, climate, vegetation, and animal life of the district, the producing placers, and the economic factors that affect mining are described by Mr. Harrington. G. C. M.

GEOLOGY.—*Mineral resources of Seward Peninsula, Alaska.* GEORGE L. HARRINGTON. U. S. Geol. Survey, Bull. **692-G.** Pp. 48 (353–400), pl. 1. 1919.

Stream tin has been found in many streams in Alaska, and lodes of cassiterite have been prospected and mined at several places in Alaska. An account of the tin deposits and tin mining in Seward Peninsula is given.

The graphite deposits of Seward Peninsula have been known for many years, but gold has so long been the most valuable mineral mined there that other minerals have not been much considered by the miner. The location of the deposits and the work that has been done on them are sketched.

The search for the sources of the placer gold found in the streams of Alaska has been a part of the work of the geologists who have been studying and mapping the topography and geology of the Territory. The author describes the geology and mineral resources of the Kowalik and Koyuk region, stating the means of communication, timber, coal, and sources of water supply, gives detailed descriptions of the gold and platinum placers, and makes suggestions as to the original sources of the metals. G. C. M.

GEOLOGY.—*A reconnaissance of the Pine Creek District, Idaho.* EDWARD L. JONES, JR. U. S. Geol. Survey, Bull. **710-A.** Pp. 36, pl. 1. 1919.

The Pine Creek district, Idaho, lies immediately west and south of the Wardner district of the Coeur d'Alene region. The Pine Creek drainage basin is underlain chiefly by sedimentary rocks of Algonkian age, termed the Belt series. These rocks are intruded by small black dikes, mainly along faults. Deposits of well-rounded gravel of Tertiary age cap many of the low hills adjacent to Coeur d'Alene River. Extensive faulting has occurred in the Pine Creek district; all these faults are of the normal type.

The ore deposits of the Pine Creek district are metasomatic fissure veins and fissure fillings, with gradations between the two types. The veins that show metasomatic replacement are best developed in shear zones along major faults; the fissure fillings are best developed along minor faults or in zones of moderate shearing. The veins are chiefly valuable for their zinc, lead, silver, and antimony content, though some contain also gold and copper. These veins are probably best classified on the basis of their dominant metal or mineral content, into zinc-lead, antimony, and siderite veins.

The best examples of the metasomatic fissure veins are those of the zinc-lead type. The most valuable ore is a fine-grained aggregate of sphalerite and galena in which there are commonly fragments of unreplaced wall rocks. Pyrrhotite accompanies the ore and in places is the chief mineral. Chalcopyrite is usually present in small amounts.

The antimony veins differ markedly from the other veins of the district in mineral composition. The principal metallic sulphide is stibnite. Pyrite is a common constituent of these veins, and here and there they contain sphalerite.

Manganiferous siderite veins occur in the southern part of the Pine Creek basin. These veins are simple fissure fillings. No important ore bodies have yet been developed in any of them.

The primary sulphide minerals of the Pine Creek district are galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, tetrahedrite, stibnite, and arsenopyrite. The minerals that resulted from the oxidation of the sulphides are cerusite, malachite, massicot, pyromorphite, and chalcocite.

Mines and prospects are described. R. W. STONE.

GEOLOGY.—*The Farnham anticline, Carbon County, Utah.* FRANK R. CLARK. U. S. Geol. Survey, Bull. **711-A.** Pp. 13, pls. 2, fig. 1. 1919.

The Farnham anticline is in the south-central part of Carbon County, Utah. The surface strata involved in the anticline are the Mancos shale, the Dakota sandstone, and the McElmo formation.

The anticline is a small uplift in a broad, gently northward-dipping monocline which was developed in the movement that produced the San Rafael Swell and Uinta Basin folds. It is about 3 miles long by three-quarters of a mile wide. The dip of the rocks affected by the anticline rarely exceeds 10° except adjacent to faults, where it ranges from 25° to 85°. Several faults cut the surface strata of the anticline and trend roughly parallel to the axis of the fold.

The Farnham anticline is structurally favorable for the accumulation of oil and gas, and the nearest exposures of Triassic and Pennsylvanian rocks contain oil seeps. These conditions appear to warrant one or more test holes of this fold, and locations for test holes are suggested. This paper concludes with a review of oil and gas prospecting in Utah.

R. W. STONE.

GEOLOGY.—*Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah.* D. DALE CONDIT. U. S. Geol. Survey, Bull. **711-B.** Pp. 26 (15–40), pl. 1, figs. 2. 1919.

In the Dillon-Dell area, Montana, where the Phosphoria oil shale is at its best, the richest beds of 3 feet or more in thickness yield 25 to 30 gallons of oil to the ton. The phosphate beds associated with the shale are thinner and contain considerably less phosphorus pentoxide than those mined near Montpelier, Idaho, and those known to occur in the Melrose and Garrison fields of Montana. Samples of the shales associated with the high-grade phosphate rock in the southeastern Idaho area yielded on distillation little more than a trace of oil.

R. W. STONE.

ENTOMOLOGY.—*The parasitic aculeata, a study in evolution.* WILLIAM MORTON WHEELER. Proc. Amer. Phil. Soc. **58:** 1–49. 1919.

After summarizing the various types of parasitism in the hymenopterous insects known as Aculeata (excepting the Scoliids and Mutillids), and presenting an interesting hypothesis as to how parasitism arose, the author summarizes his conclusions as follows:

1. "We may distinguish two intergrading types of parasitism among insects. One of these is true parasitism and is represented by the lice, fleas, Mallophaga, many Diptera (Oestridae, Pupipara) and some Hemiptera, which live on mammals and birds and do not destroy their hosts. The other is parasitoidism, which is really a refinement of predatism and is eminently characteristic of large sections of the Hymenoptera and Diptera (Tachinidae). It leads sooner or later to the death of the host. The difference between the two types is largely due to differences in the size and vigor of the hosts."

2. "Parasitoids are of two classes, one of which is best represented by the so-called Parasitica among the Hymenoptera and the Tachinidae among the Diptera, which have no genetic relationship with their hosts. The other class of parasitoids is represented by the Aculeates which have sprung directly from their host species (intraspecific parasitoids), though they may subsequently acquire hosts among other species of the same genus or of other genera and may in turn be the ancestors of parasitic species."

3. "The derivation of all the existing Aculeata from primitive insectivorous wasp-like ancestors may account for the retention of a rather uniform pattern of behavior among the parasitic species. The parasites, both among the solitary wasps and the solitary bees, behave in a very similar manner, though the former are reared on insect prey, the latter on pollen and honey.* * *"

4. "The origin of parasitism among the Aculeata may be attributed to urgency of oviposition and temporary or local dearth of the supply of provisions for the offspring."

5. "In all the different forms of parasitism among the Aculeata, there are traces of the primitive predatism or parasitoidism from which it arose, although in some of the social parasites this is represented only by the aggressive or conciliatory intrusion of the recently fecundated female into the host colony.* * *"

6. "Although many cases of parasitism are known to occur among the Aculeata, and although many others will doubtless be discovered in the future, nevertheless the total number must be small in comparison with the thousands of nonparasitic species. Contemplation of such a series as we find among the ants, beginning with *Formica sanguinea*, which is an abundant, vigorous and aggressive species, and ending with *Anergates atratulus*, a small, sporadic, and apparently evanescent species, without workers and with wingless, nymphoid males, suggests that parasitism among the Aculeates tends to such extreme specialization

("degeneration") as to lead to extinction. If we possessed a knowledge of the whole evolution of the Aculeate group, we should probably find that the total number of parasitic species which it produced during the ages was very great, but that the vast majority of them, after reaching the Anergates or a similarly specialized, or degenerate stage, lingered on precariously for a time and then disappeared."

The paper is completed with a list of the literature examined.

S. A. ROHWER.

CERAMIC CHEMISTRY.—*Devitrification of glass.* N. L. BOWEN. Journ. Amer. Ceram. Soc. **2**: 261–278. April, 1919. (Geophysical Lab. Papers on Optical Glass, No. 9.)

Devitrification of glass is the result of the tendency of the glass to reach the stable crystalline condition and takes place whenever the glass is held for a sufficiently long period of time within the range of temperature where its crystallizing power is great. The various forms of devitrification in glass are discussed from this point of view and suggestions are made as to the principles that must be borne in mind in deciding upon modifications of procedure or changes in composition that have as their object the avoidance of devitrification. Specific examples of the devitrification of optical glasses are given, together with identification of the crystalline phases separating. N. L. B.

CERAMIC CHEMISTRY.—*The volatilization of iron from optical glass pots by chlorine at high temperatures.* J. C. HOSTETTER, H. S. ROBERTS and J. B. FERGUSON. Journ. Amer. Ceram. Soc. **2**: 356–372. May, 1919. (Geophysical Lab. Papers on Optical Glass, No. 12.)

Of all the ordinary impurities found in optical glass, iron exerts the greatest influence on transmission. The iron-content of the glass arises from pots used as containers during melting as well as from the raw materials. The content of iron in the glass and, therefore, its transmission, would be considerably improved if the iron could be removed from the pot-walls before use. Chlorine appeared to be a suitable agent for this purpose, and experiments demonstrated the fact that approximately 80 per cent of the iron could be extracted from the interior of the clay pots and volatilized by the action of chlorine at temperatures easily secured in a pot-arch or glass-melting furnace. Large-scale experiments were carried out and conditions developed for removing more iron from the bottom of the pot, where the most corrosion

takes place, than from the side-walls. Glass melted in these pots showed, in all cases but one, less iron than that made in untreated pots. In the exception noted above, however, more iron was found in the glass made in the treated pot, and it was shown that, although the iron had been volatilized from the pot, more than usual pot corrosion had taken place during melting. The success of the method, then, depends on whether a dense surface can be made in such pots when the iron has been removed, as, for instance, by burning under different conditions from that obtaining during the course of these experiments. With some types of pots the method would undoubtedly be successful, even with the usual burning schedules. The possible application to the removal of iron from grog, clay, and other ceramic products is indicated.

J. C. H.

RADIOTELEGRAPHY.—*Principles of radio transmission and reception with antenna and coil aerials.* J. H. DELLINGER. Proc. Amer. Electr. Eng. **38**: 1095–1150. 1919.

Coil aerials are coming to replace the large antennas in radio work. The advantage of the coil aerial as a direction finder, interference preventer, reducer of strays, and submarine aerial, make it important to know how effective such an aerial is as a transmitting and receiving device in comparison with the ordinary antenna. In this article the mathematical theory is presented and, as a result, the answer to this question is obtained. Experiments have verified the conclusions reached, and the formulas which are obtained are a valuable aid in the design of an aerial to fit any kind of radio station.

It is found that the coil aerial is particularly desirable for communication on short wave lengths. A coil aerial is as powerful as an antenna only when its dimensions approach those of the antenna. For other reasons, however, a small coil aerial is in many cases as effective as a large antenna. It is shown that an advantageous type of radio aerial is a condenser consisting of two large metal plates. This type of aerial has many of the advantages of the coil aerial. The fundamental principles of design of aerials are given in the paper. On the basis of this work the actual functioning of any type of radio aerial can be determined either from measurements made upon the aerials or from actual transmission experiments.

J. H. D.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

820TH MEETING

The 820th meeting was held at the Cosmos Club, May 24, 1919, with President HUMPHREYS in the chair and 34 persons present. The minutes of the 819th meeting were read in abstract and approved.

The first paper, by Messrs. H. L. CURTIS and R. C. DUNCAN, on *Measurements of short time intervals*, was presented by Mr. Duncan.

Early in the war, at the request of the Navy Department, the Bureau of Standards undertook the investigation of certain factors which had to do with the firing of the 14-inch Naval guns. It was desired to measure a number of time intervals into which the total firing time of the gun may be divided and also to study the motion of the gun as a function of time. Both of these problems required the measurement of short time intervals with considerable accuracy.

The General Electric oscillograph was chosen as the apparatus for recording the events which were to be studied. A special timing system was installed in the oscillograph, which ruled on the film an equal interval time scale, consisting of sharp lines running across the film. By means of a proper optical system, light from the arc used to illuminate the mirrors of the oscillograph was caused to fall on the film after passing through a narrow slot, which was open only for very short times at regular intervals. This slot was made by fastening a slotted aluminum vane on each prong of a tuning fork and adjusting the vanes so that when the fork is at rest the slots will allow the light to pass through. As the fork vibrates, these slots are opened twice each vibration. A 500-cycle fork is used to rule the film in thousandths of a second, while the 50-cycle fork rules the film in hundredths of a second.

Considerable trouble was experienced in driving the 500-cycle fork at sufficient amplitude. Satisfactory results, however, were finally obtained by driving 500-cycle forks by means of a 100-cycle master fork. In this way the electro-magnets of the 500-cycle forks were energized once every five vibrations and by careful tuning it has been possible to get a double amplitude of nearly 2 mm. This is important, as the sharpness of the timing lines depends upon the amplitude of the fork vibrations. In order to eliminate any possible errors due to the master fork, a relay is so arranged that as the exposure is made the

driving current is broken and the timing forks, therefore, vibrate freely. A similar set-up consisting of 50-cycle forks and a 50-cycle master fork is used to rule slow-moving films into hundredths of a second.

An examination of the timing line records indicates that the lines are not equidistant, every alternate interval being slightly wider than the intervening ones. This is due to the fact that the vanes are not properly adjusted. As it was found almost impossible to adjust them exactly these errors are eliminated by interpolating between every other line. It is only necessary to do this when extreme accuracy is desired.

Further examination of the records indicates that the time exposure is extremely short, certainly not greater than 0.000 01 second. Even when the film is moving at a speed of 1500 cm. per second the lines are quite sharp.

In order to test the accuracy which could be obtained in the determination of time intervals, one film was exposed on each of two oscillographs simultaneously. One recording galvanometer on each oscillograph was put in series with a current interrupted by a tuning fork. By examining the two films, it was possible to identify the individual interruptions. Measurements were then made on both films to determine the time intervals between certain vibration rates of the two circuits. The time intervals measured on the two films varied in every case by less than 0.000 01 second.

It therefore seems that this method makes it possible to measure intervals of thousandths of a second to better than one per cent, while intervals from 0.1 to 0.2 second can be measured with an accuracy of about 0.01 per cent.

The paper was illustrated by lantern slides. It was discussed by Messrs. SILSBEE and BEAL.

The second paper was by Mr. A. F. BEAL, on *Comparison of invar with steel as shown by the rates of high grade watches.*

For watches such as the Bureau of Standards is testing for use as chronometers by the United States Shipping Board, where they are mounted so as to remain horizontal at all times, the compensation for changes of temperature is the only important known cause of variation that is not entirely within the control of the adjuster. Uniformity of rate for different temperatures depends upon the physical constants of the balance wheel and hairspring, and perfect compensation has been unobtainable with the customary steel hairspring and brass-steel balance wheel. If, in the balance wheel, invar be substituted for steel, a combination can be obtained which will show rates that are practically constant over large ranges of temperature.

During 1917 and 1918, the Bureau of Standards tested the watches supplied on two purchase orders placed by the United States Shipping Board with two American manufacturers of high grade watches. Those supplied on one of these orders (for 200 watches) had brass-

steel balance wheels and the watches were constructed from new designs in only a few months. Those submitted on the other order (for 250 watches) had brass-invar balance wheels and had been carefully developed during about five years or more. The mean of the middle temperature errors (difference of daily rate at 20°C. from the mean of the daily rates at 35°C. and 5°C.) for the 200 accepted watches with brass-steel balance wheels was 2.25 seconds, while for the 250 accepted watches with brass-invar balance wheels the mean was 0.24 second, thereby showing that invar will permit much better temperature compensation than will steel.

Following the end of the acceptance tests of these watches they were checked up each week until they were sent to the ships; the mean weekly temperatures were also observed. The rates of 30 watches with brass-invar balance wheels and 32 watches with brass-steel balance wheels were carefully corrected for the observed changes of temperature. Based upon observations for 18 weeks the mean of the probable errors of forecasting the mean daily rate for the ensuing week was 0.277 second for the brass-invar watches and 0.260 second for the brass-steel.

It was noticed that occasionally the watches with brass-invar balance wheels showed sudden permanent changes of rate corresponding to permanent changes in the inertia of the balance wheels. These occasionally amounted to 10 seconds in the mean daily rate. Following a jump of this character, the rate of a watch usually would remain practically constant at its new value. Most of the watches did not show any pronounced changes. In computing the above probable errors, there was not used any watch which showed an important change of rate. These erratic performances were not observed for the watches with brass-steel balance wheels.

The conclusion is that invar, when substituted for steel in balance wheels, will permit practically perfect temperature compensation, and will show good stability of rate; occasionally, however, sudden permanent changes of rate throw a shadow of doubt over the advisability of this substitution. This conclusion is in agreement with statements made by employees of certain watch manufacturers who have experimented on this subject, and with the reports on the stability of invar for other purposes.

The paper was illustrated by lantern slides. It was discussed by Messrs. R. Y. FERNER, C. A. BRIGGS, and W. P. WHITE.

Adjournment took place at 10.10 and was followed by a social hour.

S. J. MAUCHLY, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

MATTERS OF SCIENTIFIC INTEREST IN CONGRESS[1]

The first of the bills commented upon in this column to become law is H. R. 6810, the National Prohibition Act. At the time of the last report on this bill[2] it was before the Senate Committee on the Judiciary, which reported the bill with numerous amendments on August 18 (Report 151). The bill was debated in the Senate on September 4 and 5, and the section providing for tax-free pure alcohol for scientific purposes was modified in several respects, among which was the substitution of the words "for scientific purposes, or for the use of any hospital" in place of the words "for the use of any scientific university or college of learning, any laboratory for use exclusively in scientific research, or any hospital not conducted for profit."

The amended bill was passed by the Senate on September 5, and as the House disagreed to many of the amendments, was sent to conference on September 9. As modified by the conferees it was passed by the Senate on October 8 and the House on October 10, but was vetoed by the President on October 27 on account of the inclusion of war-time prohibition provisions. The House and Senate promptly re-enacted the bill over the veto and it became Public Law 66 on October 28.

The provision for tax-free alcohol for scientific work, as finally adopted, is as follows:

(Part of Title III, Section 11): "Alcohol may be withdrawn, under regulations, from any industrial plant or bonded warehouse tax free by the United States or any governmental agency thereof, or by the several States and Territories or any municipal subdivision thereof or by the District of Columbia, or for the use of any scientific university or college of learning, any laboratory for use exclusively in scientific research, or for use in any hospital or sanatorium."

The First Deficiency Act for 1920 (H. R. 9205), which was signed by the President on November 4 as Public Law 73, carries appropriations for the Bureau of Standards of $250,000 for industrial research, $25,000 for the study of safety standards, and $50,000 for standardization work on instruments, machinery, and equipment.

A bill "to authorize the President of the United States to arrange and participate in an international conference to consider questions relating to international communication" was introduced in October, in the Senate by Mr. LODGE (S. 3172) and in the House by Mr. ROGERS (H. R. 9822). The House bill was passed on October 22, with one amendment, providing for confirmation of the delegates by the Senate.

[1] Preceding report: This JOURNAL 9: 562. 1919.

[2] This JOURNAL 9: 423. 1919.

It is now before the Senate Committee on Foreign Relations. Among the questions to be considered are problems of wireless wave-lengths and of vessel-to-shore communication.

The Patent Office legislation, before the House Committee on Patents, was divided several weeks ago so that the bills proposing an independent patent and trade-mark department and a court of patent appeals were to be further considered by a subcommittee, while another subcommittee was to consider salaries in the Patent Office.

Dr. C. L. ALSBERG, chief of the Bureau of Chemistry, appeared in October before the Senate Committee on Agriculture and Forestry, to testify concerning the properties and uses of saccharin. The Committee had under consideration S. Res. 209, authorizing an investigation and report on "the present status of saccharin under departmental regulations and the feasibility of its wider use in the United States for the relief of the present sugar shortage."

Hearings were held on Mr. MYERS' anti-vivisection bill[3] (S. 1258) on November 1–4, before a subcommittee of the Senate Committee on the Judiciary. Representatives of various anti-vivisection organizations spoke in favor of the bill. The bill was opposed by Drs. W. H. WELCH, SIMON FLEXNER, C. W. STILES, W. B. CANNON, REID HUNT, J. B. NICHOLS, and many others, representing the medical profession of the District of Columbia and the country at large, as well as the Army and Navy and the Federal bureaus. "A public meeting to arouse feeling favorable to the bill" was held at the Public Library on October 31.

The need of research on methods for the fixation of atmospheric nitrogen is recognized in H. R. 10329 (Mr. KAHN, November 1): "A bill to provide further for the national defense; to establish a self-sustaining Federal agency for the manufacture, production, and development of the products of atmospheric nitrogen for military, experimental, and other purposes; to provide research laboratories and experimental plants for the development of fixed-nitrogen production; and for other purposes."

The bill provides for the organization of the "United States Fixed Nitrogen Corporation," with a preferred capital stock of $12,500,000, to be subscribed by the United States. Control is placed in a board of directors appointed by the Secretary of War. The Corporation is given power to acquire and operate U. S. Nitrate Plants Nos. 1 and 2 (at Sheffield and Muscle Shoals, Alabama) together with accessory plants, including the fixed nitrogen research laboratory now located at the American University in Washington; and to act as agent of the President in completing and operating the hydroelectric power plant at Muscle Shoals, as specified in the National Defense Act of June 3, 1916, but free from the limitations and restrictions imposed by that act. The bill was referred to the Committee on Military Affairs.

[3] This JOURNAL 9: 422. 1919.

NOTES

The property at 1201 Sixteenth Street, now leased and occupied by the National Research Council, has been purchased by the National Educational Association.

The Governor of the Territory of Hawaii has requested the Geological Survey to make a geological examination of the territory with reference to its ground-water resources. Field work will probably be started in January by O. E. MEINZER, W. O. CLARK, and L. F. NOBLE.

The Coast and Geodetic steamer *Hydrographer*, while surveying the Florida Reefs, was caught in the hurricane of September 9. The cables fouled those of the *Tuscarora*, and, in order to save both vessels, the officers and men of the *Hydrographer* had to be transferred to the *Tuscarora;* the cables were then slipped by mate STRAUBE and the *Hydrographer* was blown across the channel on to the shoals. The vessel was floated later and hauled out at Key West for examination. The Secretary of Commerce has sent a letter to Commander G. C. MATTISON and the men of the *Hydrographer*, commending their skill in salvaging the vessel without outside assistance.

Dr. HORACE G. BYERS, formerly of the University of Washington, who was recently appointed chemist in charge of soil investigations in the Bureau of Soils, has accepted the position of head of the department of chemistry at Cooper Union Institute, New York City.

Mr. W. J. COTTON has resigned from the Color Laboratory of the Bureau of Chemistry to accept a position with the National Aniline and Chemical Company, of Buffalo, New York.

Lieutenant Colonel COERT DUBOIS, District Forester at San Francisco, California, has resigned from the U. S. Forest Service and entered the Consular Service. Colonel DuBois had been a member of the Forest Service since 1900.

Mr. CHESTER G. GILBERT resigned from the Smithsonian Institution on October 1, to accept a position on the staff of Arthur D. Little, Inc., of Cambridge, Massachusetts. This organization has opened a Washington office in the Munsey Building, with Mr. Gilbert in charge.

Mr. F. W. GLADING, of the Bureau of Standards, has resigned to become Industrial Engineer for the Baldwin Locomotive Works, at Philadelphia, Pennsylvania.

Dr. ALES HRDLICKA has been made an honorary member of the Association Liégois pour l'Étude et l'Enseignment des Sciences Anthropologiques, at Liége, Belgium.

Dr. GRINNELL JONES, chemist to the Tariff Commission, has returned to Harvard University but is still retained in an advisory capacity by the Commission.

Dr. D. J. KELLY, first assistant examiner in Division 31 of the Patent Office, died on July 24, 1919. He had been connected with the Patent Office since 1880, and had become an authority on the development of the mineral oil industry.

Dr. G. F. LOUGHLIN, of the Geological Survey, is giving a course of lectures on metalliferous geology at the Massachusetts Institute of Technology, temporarily filling the place of Professor WALDEMAR LINDGREN.

Mr. H. A. NELSON, formerly of the Bureau of Standards, is now with the New Jersey Zinc Company.

Mr. C. G. QUILLIAN, of the U. S. Coast and Geodetic Survey, has laid out a speed-trial course for the use of aircraft in the vicinity of Rockaway Beach, Long Island, at the request of the Navy Department.

Dr. L. W. STEPHENSON, of the Geological Survey, has been granted a six months' leave of absence in the early part of 1920, in order to do stratigraphic work for one of the oil companies in the Tampico oil field, Mexico.